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MINERALOGICAL INVESTIGATION OF THREE FERROSILICON SAMPLES FROM CHROMASCO, HALEY, ONTARIO

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MINERALOGICAL INVESTIGATION OF THREE FERROSILICON SAMPLES FROM CHROMASCO, HALEY, ONTARIO

by

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ABSTRACT

A mineralogical investigation of three ferrosilicon samples of varying quality from Chromasco, Haley, Ontario did not establish a clear relationship between the reactivity of the three ferrosilicons and their chemical composition or liberation. The poorest quality ferrosilicon was definitely finer-grained than the others and this fineness may adversely affect its reactivity by reducing the porosity of the briquette.

INTRODUCTION

Chromasco operates a plant at Haley, Ontario which produces magnesium metal by the Pidgeon process. Ferrosilicon is used in the process as a source of silicon which acts as a reducing agent in the production of magnesium according to the reaction

$$2CaO.MgO + Si \rightarrow Ca_2SiO_4 + 2Mg(g)$$

Recently the recoveries of magnesium metal have in some instances dropped below acceptable levels. As part of a general investigation to determine the source of this problem Chromasco is investigating the chemical and physical nature of the ferrosilicon.

Three samples of ferrosilicon were received from A. Froats, Chief Metallurgist at Chromasco. The samples were labelled C633, C634 and C723 and were graded as good, poor and fair respectively, according to the resultant reactivity of the ferrosilicon. Mr. Froats initially requested a quantitative analysis of the samples for SiO_2, FeSi, $FeSi_2$ and Si. Each sample was mounted as a polished section and examined by the SEM. After an initial examination it was agreed that a full mineralogical investigation was required which should include identification of all phases present, the composition of the phases, the quantities of the phases and the size distribution of the ferrosilicon and silicon.

PHASES AND COMPOSITIONS

The phases identified in the samples are silicon, four types of ferrosilicon and two phases containing Ca-Si. Quantitative analyses of the phases were performed with the electron microprobe using the energy dispersive X-ray analyser. The range of compositions for each identified phase was relatively constant from grain to grain in all samples. The phases identified and their compositions are shown in Table 1 where the averages of the analyses are presented. The silicon is present as grains of pure Si while the second major phase, $FeSi_2$, contains a slight excess of silicon over the stoichiometric requirements of the formula. No silica, free iron, CaSi or FeSi, were detected.

Table 1. Quantitative Analysis of Phases (wt %)

Phase	Fe	Ti	Cr	Mn	Ca	Al	Si	Total	No. of Analyses
Fe-Ti-Si	34	27	1	1	-	-	37	100	4
Fe-Cr-Ti-Si	4	25	15	1	-	-	55	100	2
$FeSi_2$	44	-	-	-	-	-	56	100	20
Ca-Al-Fe-Si	36	-	-	1	6	22	35	100	8
$CaSi_2$	1	-	-	-	42	-	57	100	1
Al-Ca-Si	-	-	-	-	31	5	64	100	1
Si	-	-	-	-	-	-	100	100	20

PHASE QUANTITIES

Using the scanning electron microscope-based image analyzer, the relative quantities of each of the phases observed in the polished sections were determined by measuring their % relative areas over a sufficient portion of each section to be representative of the total section. These measured % relative areas are assumed to be equal to % relative volumes which are then converted into wt % for each phase by multiplying its relative volume by the specific gravity of that phase. Densities for $FeSi_2$, $CaSi_2$ and Si were obtained from the literature; the others were estimated. The results given in Table 2 are reported to two decimal places for the sake of data coherence. The 95% confidence limits are approximately ±1% absolute.

Table 2. Quantities of Phases (wt %)

Phase	Specific Gravity	Sample No.		
		C633	C634	C723
Fe-Ti-Si	6.0	1.10	1.03	1.55
Fe-Cr-Ti-Si	6.0	0.27	0.12	0.22
$FeSi_2$	6.7	36.21	32.82	49.68
Ca-Al-Fe-Si	5.0	1.88	1.64	0.33
$CaSi_2$	2.5	1.53	1.42	0.42
Ca-Al-Si	3.0	1.82	0.89	0.23
Si	2.33	57.03	62.08	47.57
SiO_2 (?)	2.65	0.16	NIL	NIL
		100.00	100.00	100.00

SiO_2 was never specifically detected by the microprobe but in sample C633, a small quantity of a phase with an average atomic number of less than 14 was detected and that phase was assumed to be silica.

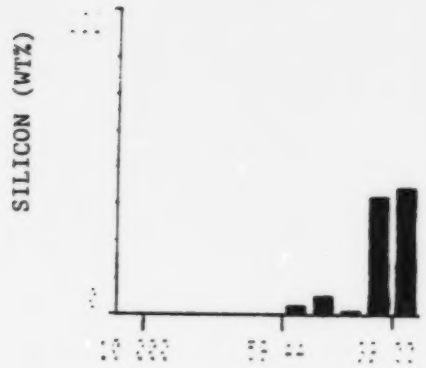
Using the phase distribution in each sample and the proportion of Si in each phase the total Si was calculated for each sample. The results are compared with data supplied by Chromasco in Table 3. The discrepancy with regard to sample 633 may be due to the polished section not being representative.

Table 3. Total Silicon Content (wt %)

	Sample No.		
	C633	C634	C723
Calculated	80.64	82.86	76.59
Reported by Chromasco	84.4	83.4	76.7

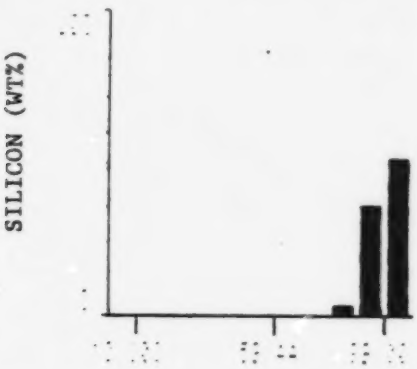
PHASE RELATIONSHIPS

The major phase, silicon, occurs mostly as free grains. Figures 1-3 show the weight distribution of the silicon in various classes of composite grains. Figures 4 and 5 are photomicrographs showing free silicon grains in sample C634. Figures 6 to 8 show the weight distribution of the ferrosilicon phase, $FeSi_2$, in various classes of composite grains. $FeSi_2$ is rarely completely free but exists in composite grains which are at least 80% $FeSi_2$, by volume. The $FeSi_2$ is usually locked with silicon in a simple manner as is shown in Figures 9 and 10. The other minor phases when present are usually associated with $FeSi_2$ as is shown in Figure 11.



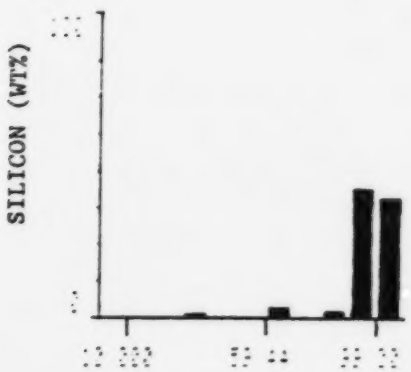
Silicon Content Per Particle (Vol %)

Fig. 1. Silicon distribution histogram of sample C633



Silicon Content Per Particle (Vol %)

Fig. 2. Silicon distribution histogram of sample C634



Silicon Content Per Particle (Vol %)

Fig. 3. Silicon distribution histogram of sample C723

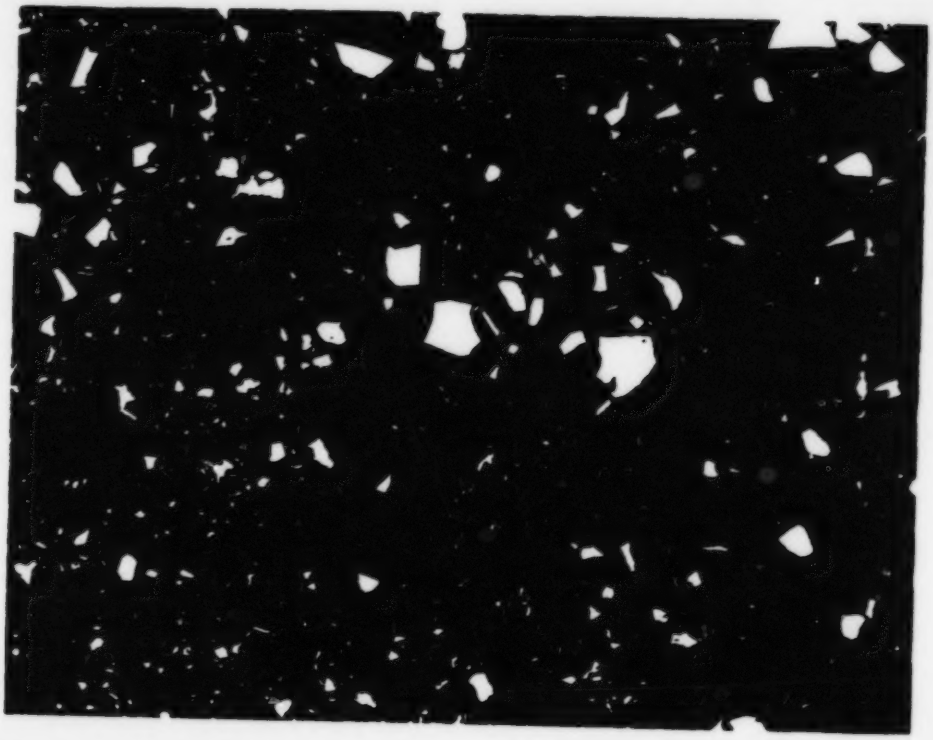


Fig. 4. Backscattered electron (BSE) photomicrograph of typical field of view of sample C634 showing large free silicon grains (grey) and smaller ferrosilicon grains (white)

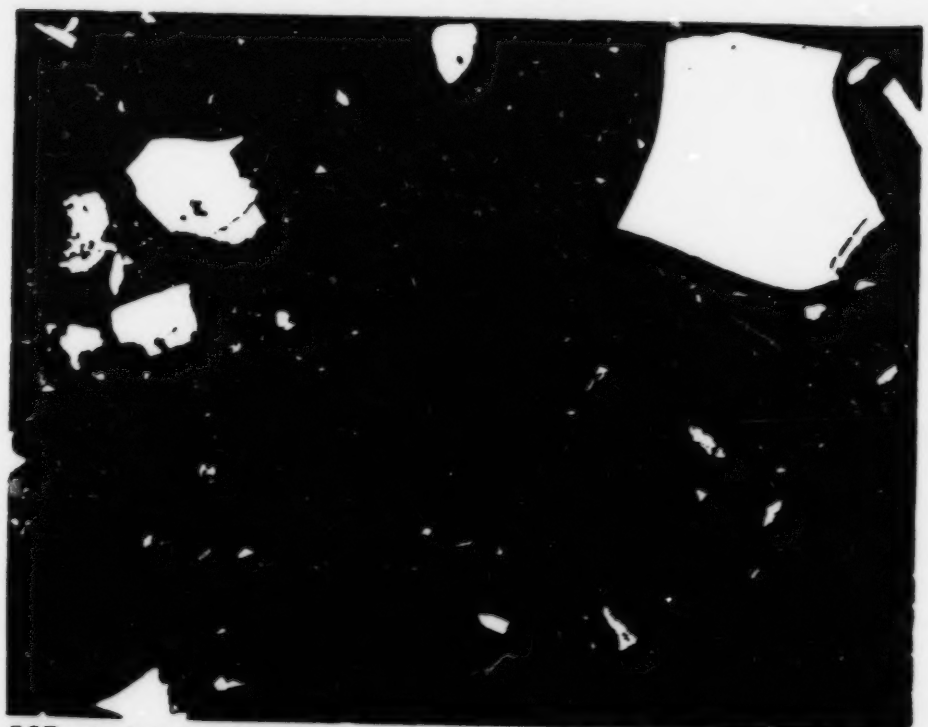
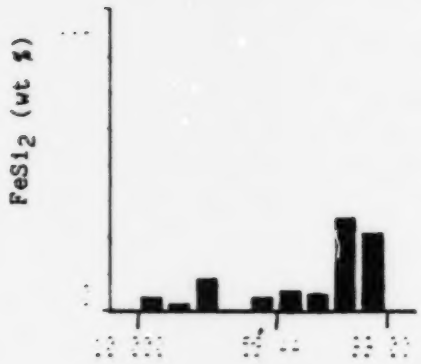
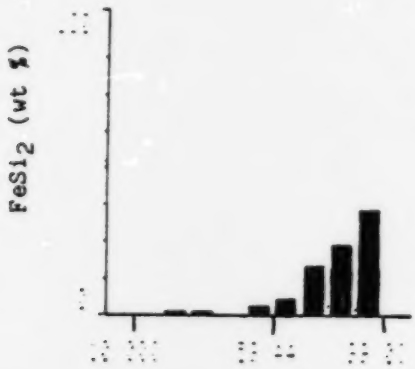


Fig. 5. A BSE photomicrograph of the centre portion of Fig. 4 at a higher magnification showing the fine-grained texture of sample C634



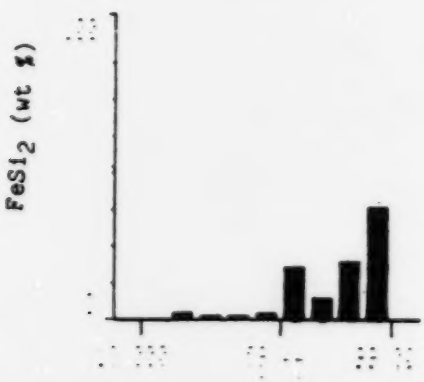
$FeSi_2$ Content Per Particle (Vol %)

Fig. 6. $FeSi_2$ distribution histogram of sample C633



$FeSi_2$ Content Per Particle (Vol %)

Fig. 7. $FeSi_2$ distribution histogram of sample C634



$FeSi_2$ Content Per Particle (Vol %)

Fig. 8. $FeSi_2$ distribution histogram of sample C723

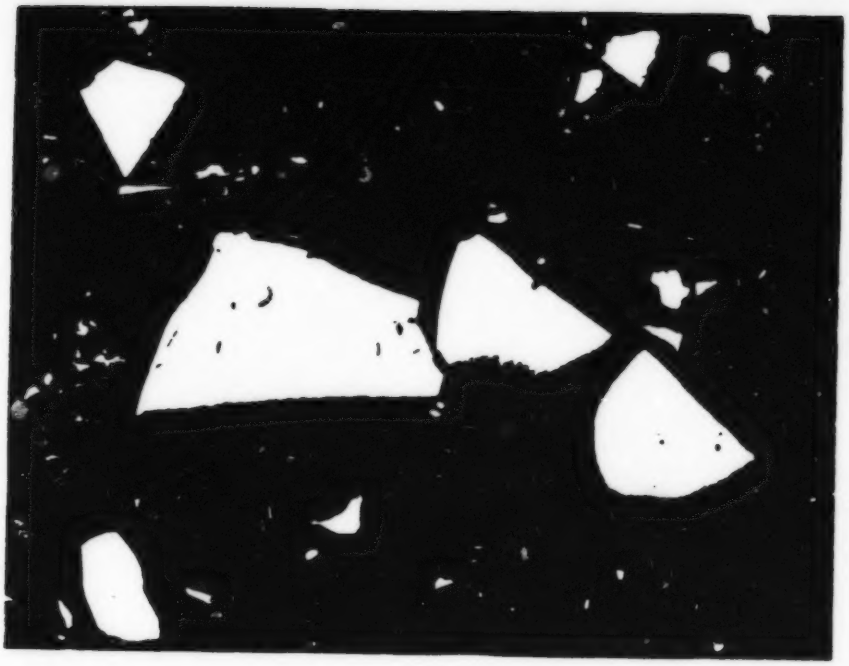


Fig. 9. BSE photomicrograph of some grains containing $FeSi_2$ (white) locked with Si (grey)

Fig. 10. BSE photomicrograph of some grains containing $FeSi_2$ (white) locked with Si (grey)

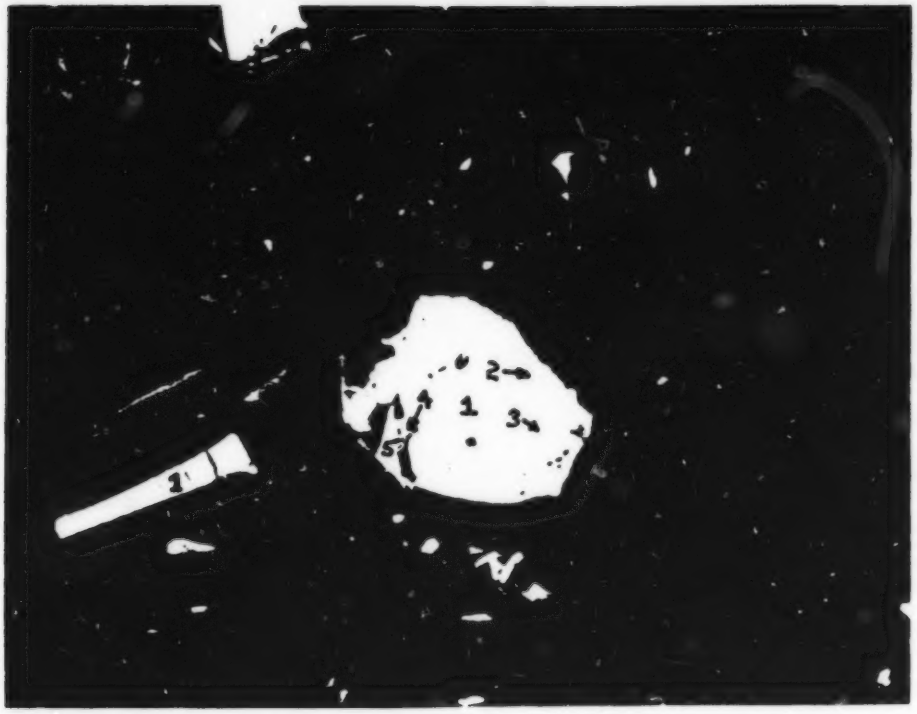


Fig. 11. BSE photomicrograph showing the association of the minor phases with $FeSi_2$

1. $FeSi_2$
2. Ca-Al-Fe-Si
3. Fe-Cr-Ti-Si
4. Ca-Si
5. Fe-Ti-Si
6. Si

SIZE DISTRIBUTIONS

The size distributions of the Si and $FeSi_2$ grains in each sample were measured using the image analysis system and are shown in Table 4. These results show that for sample C634 53% of the Si phase is less than 26 µm. When this is compared with 38% for C633 and 36% for C723 it can be concluded that C634 is significantly finer-grained.

Table 4. Size Distributions of the Si and $FeSi_2$ Phases (wt %) (expressed as cumulative wt % passing)

Size (µm)	C633		C634		C723	
	Si	$FeSi_2$	Si	$FeSi_2$	Si	$FeSi_2$
4.6	2.5	0.8	3.9	2.3	2.2	0.6
6.5	5.9	3.3	9.3	6.5	5.6	2.2
9.2	11.0	6.3	16.8	7.4	10.9	5.2
13.0	17.91	12.4	27.6	23.8	18.0	9.4
18.4	26.81	17.9	39.2	35.3	26.5	15.6
26.0	37.71	31.1	52.8	55.2	36.3	26.6
36.8	51.0	43.3	67.5	68.7	48.7	39.3
52.1	67.7	65.6	77.4	82.3	64.4	60.1
73.6	79.2	79.8	89.3	100.0	78.9	69.0
104.0	100.0	100.0	93.6	100.0	92.2	82.7
147.0	100.0	100.0	100.0	100.0	97.5	100.0
208.0	100.0	100.0	100.0	100.0	100.0	100.0

SUMMARY

The three samples of ferrosilicon contain several phases which are relatively constant in chemical composition in all three samples. The most abundant phase is Si which is present mainly as free grains. The other major phase is ferrosilicon which is present as $FeSi_2$. The distribution of the various phases show no relationship or trend with respect to the reactivity of the three reductants, nor does the calculated total silicon content of each sample. The grain-locking of the major silicon-bearing phases also shows no relationship.

The only anomaly worthy of note is the fact that sample C634 is significantly finer-grained than the other two. This fact implies that there may be an optimum size range for ferrosilicon in the reduction reaction. It is possible that briquette porosity is being adversely affected by the ultrafine ferrosilicon. It is suggested that this idea be investigated further.